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THE MOST IMMEDIATE AND COST-EFFECTIVE WAY TO ADDRESS VEHICLE CORROSION IN HAWAII

by

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December, 1997

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THE MOST IMMEDIATE AND COST EFFECTIVE WAY TO ADDRESS VEHICLE CORROSION IN HAWAII

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ABSTRACT

In the late 1980s the Marine Corps procured the M900 series 5-ton truck. Within four years of this acquisition, a serious corrosion problem developed with the M900 series truck. Efforts to control this corrosion have proven to be unsuccessful. The current maintenance budget does not adequately fund the corrosion program nor are the facilities and procedures able to handle the workload. The objective of this thesis was to identify the most immediate and cost-effective way to handle corrosion control in Hawaii by analyzing the environment in which the Marine Corps units in Hawaii operate and recommend the most reasonable solution given the constraints. Research included an analysis of the background of Marine Corps equipment in service in Hawaii, as well as an identification of alternative measures of corrosion control management. Four alternatives were identified and evaluated in terms of the associated costs, manpower requirements, vehicle turnaround time, throughput capacity, and USMC controls. It was determined that the current corrosion control process is not adequate, and if left unchanged, the Marine Corps will face an overwhelming amount of deadlined vehicles before the replacements are available. The analysis concludes that the current method of corrosion management is inefficient. Alternative recommendations are then provided for more efficient use of the resources.

TABLE OF CONTENTS

I. INTRODUCTION

In a time of massive budget cuts, the United States Marine Corps is analyzing all its processes and procedures to find ways to save money by doing things more efficiently. One particular area that needs to be scrutinized is the corrosion control process for Marine tactical vehicles in Hawaii. Until recently, corrosion control has not been given due attention because the defense budget was large enough to replace and rebuild "unserviceable" vehicles and equipment. As the defense budget has decreased, making the current equipment last into the distant future is receiving more and more emphasis. Higher authorities are recognizing that the budget is no longer sufficient to replace vehicles, when Marine units do not maintain their equipment to standard.

This thesis will analyze the corrosion control process in Hawaii for inefficiencies and safety issues. In addition, the environmental protection agency issues, specific to Hawaii, will be addressed in the analysis and the solutions. Finally, this thesis will provide solutions that are in the best financial interest of the United States Marine Corps.

A. OBJECTIVES OF THE RESEARCH

The objective of this thesis is to determine the most cost-efficient means for the Marine Corps to implement an effective corrosion control program. It is important for the Marine Corps to establish this policy in order to restore current tactical ground equipment and ground support equipment to full operational status while maintaining the assets over the long term.

B. SCOPE

The thesis will analyze what corrosion does to operability and combat readiness. It will include a cost benefit analysis of the various corrosion control alternatives in Hawaii.

The thesis will examine the current organizational structure and process for combating corrosion in an attempt to point out the specific areas where manpower and appropriated funds are used inefficiently.

The thesis will review current and alternative corrosion control systems, summarize the Environmental Protection Agency regulations applicable in Hawaii, and present a cost benefit analysis of the various corrosion control alternatives in Hawaii. It will also recommend whether the United States Marine Corps should outsource their corrosion control to the civilian sector.

C. METHODOLOGY

This thesis will examine the problem of corrosion for Marine Corps tactical equipment. Data and background material will be collected from a literature review searching out EPA regulations, the current corrosion control system, current policies, current directives and alternative options to control corrosion. Further information will be collected from Headquarters Marine Corps, Force Service Support Group-3, Fleet Marine Force Manuals, the USA Tank-Automotive and Armaments command, OshKosh Truck corporation, AM General, as well as interviews. Additional information was obtained through a review of current military periodicals, journals, and the Internet.

D. RESEARCH QUESTIONS

The primary research question is the following: What is the most immediate and cost-effective way to address vehicle corrosion in Hawaii?

Subsidiary questions to be addressed in assessing the costs and benefits associated with the possible outsourcing of corrosion maintenance:

- What is corrosion control?
- What are the four levels of corrosion control and how are these levels performed in Hawaii?
- How is the Marine Corps managing the corrosion control program?
- How are military commands in Hawaii managing corrosion control issues in light of stringent environmental regulations?
- How is the shrinking military budget affecting corrosion control?
- How is private industry dealing with corrosion control issues?
- What options are available to reduce corrosion?
- What are the costs/ benefits/ advantages/disadvantages associated with these options and are these alternatives compliant with USMC and EPA regulations?

E. BENEFITS OF THE RESEARCH

This thesis will provide information to 3rd Force Service Support Group and to agencies located at Headquarters Marine Corps regarding the most cost-efficient means to counter corrosion on Marine Corps assets located in Hawaii. It will identify cost-effective proposals to extend the expected life of Marine Corps assets.

F. CHAPTER OVERVIEW

Chapter II will present the background of the environment in which Marine Corps' equipment operates as well as the relevant, EPA regulations, budget constraints, and the long-term effects of corrosion control.

Chapter III describes the research collection of the current corrosion control policies, environmental concerns, and corrosion coatings.

Chapter IV will analyze the alternative measures in which corrosion management can be conducted.

Chapter V will discuss conclusions and recommendations. In addition, it will recommend a course of action for the Marine Corps units in Hawaii and identify topics for future research.

II. BACKGROUND

Marine Forces have operated in Hawaii for many years. The Marines' equipment needs regular maintenance to ensure that it is ready for combat given little or no notice. Marine Corps tactical ground and ground support equipment are particularly susceptible to corrosion and other moisture intrusion damage due to their assigned missions and moisture-laden environments. Compounding the problem, a significant portion of Marine Corps ground equipment is stored outside without shelter and subject to the direct effects of the corrosive environment. [Ref. 13]

During the 1980s, the 1st Marine Expeditionary Brigade (MEB) had a contract with a civilian vendor to sandblast and paint 1st MEB's engineering and motor transportation assets on a 36-month rotational basis. In 1990, when the new M998s and M813s arrived, the MEB canceled the contract because the new equipment would not need to be repainted. By 1993 the MEB identified a big corrosion problem and designated Maintenance Company of Combat Service Support Group 3 (CSSG-3) to grind and repaint all the MEB's assets on a 36 month rotation basis. This would be done with III MEF Fleet Assistance Program (FAP) from 3rd Marine Regiment and Marine Aircraft Group twenty-four (MAG-24). Due to the severity of the problem, cabs on most of the vehicles needed to be replaced after 18 months. [Ref. 4]

Current Environmental Protection Agency (EPA) regulations prohibit equipment operators from performing corrosion-preventative maintenance control due to the local sensitive environment. Without maintenance the equipment inevitably deteriorates and becomes expensive to repair. When it is necessary for support units to perform this high-

level, corrosion-preventative maintenance, the current makeshift facilities are backlogged and equipment turnaround time exceeds 90 days. [Ref. 3]

1st MEB ceased to exist in 1994. As 1st MEB went away so did the budgets attached to the remaining units. A large part of the budget for maintenance came from 1st MEB. Hence, there were and continue to be significant funding shortfalls for all levels of asset maintenance in Hawaii. [Ref. 5]

A. CORROSION ENVIRONMENT IN HAWAII

Marine equipment in Kaneohe Bay, Hawaii (island of Oahu) is subject to corrosion conditions that may be the most severe within the Marine Corps. This equipment, belonging to the 3rd Marine Regiment, is exposed to frequent early morning salt-water fogs. Additionally, due to the unusual topography of Oahu, the windward side of the island experiences a high incidence of intermittent showers followed by brilliant sunshine. The combined effect of this "micro-climate" phenomena is that salt-water fog routinely coats relevant equipment. Intermittent showers then partially wash down the salt-water fog residue. However, the salt residue remaining on the equipment is highly concentrated and trapped in the equipment's channels and crevices. The high concentration of salt in the trapped moisture creates a very aggressive electrolyte in the crevice and channel corrosion process.

In addition, the equipment is primarily transported by barges to the unit's principal training area, the Pohakuloa Training Area (PTA) located on the island of Hawaii. During transportation, the equipment is exposed to salt-water environments for

periods extending from 24 to 48 hours. The salt water is a very aggressive electrolyte in the corrosion process, most notably in crevice and channel corrosion. [Ref. 7]

Once the equipment reaches the PTA, it usually remains there for three months while being used for training. As the PTA is located several miles from the shoreline, the exposure to salt air is far less than the equipment exposure on Oahu. However, the island of Hawaii is a site of active volcanoes. These volcanoes release gases made up of sulfur and other corrosive substances. When these gases combine with rainwater, it creates highly corrosive acid rain. This acid rain attacks exposed metal surfaces and is a very aggressive electrolyte in the corrosion process. [Ref. 7]

B. CORROSION

Corrosion will be defined, for the purposes of this thesis, as unwanted chemical reaction between a metallic material and its environment, which reduces the strength or other properties essential to the performance of a given item or system. [Ref. 18] Corrosion control can be handled by two different means: preventive or corrective corrosion control.

1. Preventive Corrosion Control

Corrosion prevention really starts in the acquisition phase of a material program. This most critical phase identifies, develops, and implements state-of-the-art technologies and processes to directly prevent corrosion. While it is critical to address and improve corrective corrosion control initiatives, a fundamental long-term reorientation and redistribution of effort from corrective to preventive corrosion control

appears cost-effective. [Ref. 13] This thesis will not address material acquisition but, rather, focuses on legacy equipment currently operating in the field.

2. Corrective Corrosion Control

Given the large amount of fielded equipment, it is important to identify, develop, and implement technologies and processes to correct current equipment deficiencies resulting from corrosion and moisture intrusion damage. Because of poor equipment design and manufacturing deficiencies, the Marine Corps is currently experiencing severe equipment corrosion problems resulting from the environmental impact of seaborne-transit and outdoor storage. [Ref. 13] The situation in the field must be addressed.

C. CORROSION PREVENTION AND CONTROL (CPAC) PROGRAM

The CPAC program has been established to extend the useful life of Marine Corps tactical ground and ground support equipment. In addition, CPAC attempts to reduce maintenance requirements and associated costs by identifying, implementing and, if necessary, developing corrosion prevention and control technologies and processes. These technologies and processes repair existing corrosion damage and prevent, or significantly retard, future corrosion damage on Marine Corps tactical ground and ground support equipment. [Ref. 13]

D. CORROSION CONTROL CATEGORIES OF MAINTENANCE

The Marine Corps manages corrosion control by breaking down the responsibilities into three categories and five echelons. These categories are the basis for all maintenance that is performed on Marine Corps equipment.

1. Organizational Maintenance

The foundation of all Marine Corps vehicle maintenance is organizational maintenance. This category of maintenance is conducted by the owning units; i.e. the operators. If the unit's maintenance program is effective, the unit will have a high percentage of its equipment available for missions. On the other hand, if the program is not effective and neglects organizational maintenance, serious equipment damage may result and equipment will not be available for operations.

Organizational maintenance includes both corrective and preventive maintenance. Corrective maintenance (CM) takes actions to remedy a failure. Corrective maintenance is designed to restore equipment to a specific condition. Preventive maintenance (PM) includes operation, inspection, service, lubrication, and minor adjustments. Both the CM and PM involve the replacement of parts and minor assemblies and both are designed to maintain equipment in a satisfactory operating condition.

Maintenance functions are placed into echelon (levels) that correspond to the categories of maintenance. Organizational maintenance includes first and second echelons of maintenance. [Ref. 14]

a. First Echelon

First echelon maintenance consists primarily of the user operating the

equipment correctly and inspecting, cleaning, lubricating, and making minor adjustments. An example of this would be the wire brushing of surface rust off a metal body pane. Just as organizational maintenance is the foundation of the whole maintenance system, first echelon maintenance is the foundation of good organizational maintenance. [Ref. 12]

b. Second Echelon

Specially trained personnel, such as the mechanics assigned to owning units, perform second echelon main. Their duties include inspecting, performing scheduled preventive maintenance (PM) services, making major adjustments, replacing parts and minor assemblies, and providing the operator technical assistance. The replacement of brake shoes falls within second echelon maintenance. [Ref. 12]

2. Intermediate Maintenance

Maintenance activities that are in direct support of the owning units are designated intermediate maintenance. Intermediate maintenance normally involves the replacement and repair of parts and sub-assemblies and the limited repair of major assemblies. Intermediate maintenance units also support owning units by providing technical assistance, mobile repair teams, and repair parts. Intermediate maintenance includes third and fourth echelon of maintenance. [Ref. 14]

a. Third Echelon

Maintenance personnel directly supporting operating organizations perform

third echelon intermediate maintenance. Third echelon maintenance activities are authorized a machine shop and have more specialized tools than organizational maintenance. They also have the authority to order a larger assortment of parts, subassemblies, and assemblies than owning units. They repair or replace parts, subassemblies, and major assemblies. An example of third echelon maintenance would be replacing or rebuilding the master brake cylinder. [Ref. 12]

b. Fourth Echelon

Units performing fourth echelon maintenance normally have semi-fixed or permanent shops. A fourth echelon shop has more elaborate facilities and more mechanics than a third echelon maintenance shop. It is limited only by the authorized tools, test equipment and repair parts. Complete vehicle diagnostic tests fall within fourth echelon maintenance.

Fourth echelon maintenance is the highest level of intermediate maintenance. Mechanics at this echelon are primarily responsible for repairing or rebuilding subassemblies or major assemblies. Any equipment requiring more specialized repair or a complete rebuild is forwarded to a fifth echelon maintenance facility. [Ref.12]

3. Depot Maintenance

Depot maintenance is the highest category of maintenance, fifth echelon. There are only two depot maintenance facilities within the Marine Corps: Marine Corps Logistics Base (MCLB), Albany Georgia and Marine Corps Logistics Base, Barstow, California. Depot level maintenance involves major overhauling or completely

rebuilding parts, sub-assemblies, and end items. This includes manufacturing repair parts, performing modifications, testing, and reclamation. [Ref. 12] Fifth echelon, the highest maintenance level, normally supports the supply system. Functions include rebuilding parts and sub-assemblies or overhauling complete items. Fifth echelon maintenance is normally performed at the MCLBs or by civilian contract. [Ref.12]

III. RESEARCH DATA COLLECTION

The following chapter outlines the most immediate and cost-effective way to address vehicle corrosion in Hawaii. The first section of this chapter details the corrosion control policies and practices currently used in Hawaii. The second section describes the role the Environmental Protection Agency plays in Hawaii's corrosion control policies and practices. The third section outlines corrosion's current budgetary situation and restrictions. The fourth section covers the overall cost effects of corrosion on vehicles and equipment in Hawaii. The final section of this chapter describes two process modifications that would better combat corrosion.

A. CURRENT CORROSION CONTROL POLICIES/PRACTICES

This section details current corrosion control policies and practices to address Hawaii's local environmental conditions. The restrictive environmental conditions in Hawaii preclude the normal first and second echelon corrosion control process. In Hawaii corrosion prevention and control (CPAC) measures are restricted due to environmental concerns.

1. Motor Stables

Organizational level corrosion control is typically labeled "rust busting." It is common for units with numerous vehicles and motor transport (MT) personnel to hold weekly "motor stables." These motor stables provide a closely supervised and structured setting to perform operator level required preventative maintenance (PM) and corrective maintenance (CM) practices. The motor stables are located at the motor pools

to facilitate the operator PM/CM effort. This also allows the MT mechanics, which typically supervise the motor stables, to quickly return to their organizational mechanic duties after concluding the motor stables. All the necessary tools, lubricants, and shop overhead supplies are available to support the weekly motor stables. [Ref. 7]

Conventionally, wire brush removal of spot corrosion and spot repainting are a part of the motor stables effort. Unfortunately, Hawaiian environmental restrictions prevent these corrosion correction techniques except in a single facility on Kaneohe Bay. [Ref. 2] This facility is separate from all of the 3rd Marine Regiment's motorpools. Therefore, performing the needed work at this location would be costly and time consuming.

2. Self-imposed Time Constraints

The opportunities for holding the weekly motor stables at the remote facility are limited due to time and cost constraints. Motor stables involve driving the vehicles to the motorpool, where first and second echelon maintenance is conducted. Motor stables substantially impact a command's resources as they require the MT mechanics and incidental drivers to spend four or more hours away from their units to properly perform relevant PM/CM measures. Motor stables, though demanding on a unit's resources, have proven to be a workable solution for maintaining the quality of incidental driver's PM/CM efforts.

Conducting motor stables at any location except a motorpool, or a similarly conveniently located area, requires extensive scheduling and logistical concerns. The

time spent traveling to and from the remote site increases the time that the Marines are away from their primary duties. The result adversely affects the unit's mission.

3. Washdowns

Immediately after exposure to salt water, equipment is washed down with fresh water to remove salt from the equipment. Again, due to local environmental restrictions, 3rd Marine Regiment is unable to wash down barged equipment at the loading/unloading site on the island of Hawaii. While washdowns would be permitted on the equipment when it reaches the Pohakuloa Training Area (PTA), there is inadequate fresh water and no oil/water separator. The PTA has neither a well nor a municipal water source. Currently, all fresh water is trucked to the site. [Ref. 7]

Due to the inconvenience and expense described above, barged equipment is not washed down with fresh water in a timely manner. This promotes corrosion and reduces the time before equipment requires either major refurbishment or repair parts replacement at the Combat Service Support Group-3 Intermediate Maintenance Facility (IMA). This facility is located in the garrison area at Kaneohe Bay.

4. IMA Facility

In the late 1980s, the M998s and M813s started showing signs of serious corrosion. Funding was unavailable to evacuate these vehicles to Marine Corps Logistics Base (MCLB) Barstow CA, or to reestablish a contract with an outside contractor. As a result, the CSSG-3 IMA corrosion facility was established in 1993. This "makeshift" facility was to perform similar repairs to that of the depot maintenance activity (DMA).

However, the facility is not (1) manned by trained personnel, (2) EPA compliant, or (3) funded to the needed level.

Line unit Marines from 3rd Marine Regiment and MAG-24 are assigned to the CSSG-3 IMA corrosion control facility through the fleet assistance program (FAP). This is done because the table of organization (T/O) does not allocate sufficient manpower to support the corrosion facility. These line unit Marines perform corrosion control on all the Marine vehicles in Hawaii.

The makeshift corrosion control facility, capable of housing two 5-ton trucks or 4 high mobility multi wheeled vehicles (HMMWV), can currently perform corrosion control up to echelon four. The facility can only accommodate equipment up to the size of a 5-ton truck. In order to properly prepare a 5-ton truck for corrosion protection coatings, the metal surfaces need to be sand or grit blasted. This is conducted in the corrosion facility, interrupting all other corrosion work. In addition, the process just described is not environmentally compliant. The facility is covered, but does not have devices to contain contaminants. These contaminants are able to drift into the external environment.

The preferred equipment maintenance cycle is 24 months; every 24 months, each vehicle should go through corrosion prevention/repair. Due to the facility limitations, the rotation target in Hawaii is extended to 36 months. On average, eight pieces of equipment can be processed per week. This is limited by manpower requirements. Table 3-1 shows that there is a throughput shortfall of 336 pieces of equipment in a 24-month cycle. However, there is sufficient throughput capacity to accommodate

equipment in a 36-month cycle. With a 24-month cycle the shortfall would have to be processed at another facility. The table shows transportation costs if the work is accomplished at the DMA at Barstow CA. The cost of sending one 5-ton truck to Barstow is $6,600 for the round trip.

The costs to transport the overflow equipment through the standard process are very high. This standard process involves sending equipment to the depot maintenance activity (DMA) in Barstow CA for a complete rebuild. Table 3-1 shows the cost of the overflow of equipment based on the cost of a 5-ton truck. This is $6,600 round trip.

TABLE 3-1

PIECES OF EQUIPMENT IN ROTATION CYCLE

	Vehicles Per Month	Total Completed in Cycle	Overflow	Transportation Cost to DMA
24 Month	36	864	336	$2.3 Million
36 Month	36	1200 (100%)	0	$0

5. Pearl Harbor Naval Shipyard

Pearl Harbor Naval Shipyard (PHNS) provides facilities to maintain United States Navy ships. The drawdown in U.S. Naval forces has decreased work levels at the shipyard. The shipyard has the ability and capacity to perform corrosion control on the Marine Corps'equipment. If necessary, they are able to initiate a second work shift to maintain the Marine Corps' equipment. They utilize facilities that are compliant with Federal, State, and Occupational Safety Hazard Association (OSHA) regulations. The

CSSG has been sending the most corroded vehicles to PHNS for the past three months. Marine Corps funding is not available to more fully utilize the facility.

Table 3-2 itemizes corrosion repair costs for 715 pieces of the most severely corroded equipment and vehicles at PHNS. The price is the average cost per piece of equipment without regard to the extent of corrosion damage. The annual cost for control corrosion on all 1200 pieces of equipment was not available. However, based on the mix of equipment in this table 3-2, it would cost $3 million in rough order of magnitude to cycle the 1200 pieces of equipment through the facility on a 24 month rotation. This would required an annual budget of $1.5 million for corrosion maintenance.

B. ENVIRONMENTAL CONSTRAINTS

The Resource Conservation Recovery Act (RCRA) is the environmental law that covers Marine equipment maintenance. Corrosion prevention at the first and second echelons requires the operator to bust rust with wire brushes and chip Chemical Agent Resistant Coating (CARC) paint. Rust busting releases CARC dust particles, containing trace amounts of cadmium and chromium. These traces could wash into a waste stream runoff or be blown into an environmentally sensitive wildlife area. The cadmium and chromium levels surpass the limitations set forth in RCRA. Thus, the paint is considered a hazardous material and requires special handling and protective masks. [Ref. 30] In addition, OSHA regulation CFR 29 part 1910 regulates personnel exposures to these contaminants. These restrictions hamper the entire corrosion control process by limiting operator-level corrosion prevention.

TABLE 3-2

COST ESTIMATE FOR CORROSION CONTROL AT PHNS FOR FY98

TAM#	NOMENCLATURE	TOTAL	UNIT PRICE	TOTAL PRICE
A1935	AN/MRC-138	40	$2,000	$80,000
A1955	AN/MRC-142	12	2,000	24,000
A1957	AN/MRC-145	43	2,000	86,000
B0443	HIGH SPEED CRANE	2	7,000	14,000
B0446	7 ½ TON CRANE	2	6,000	12,000
B2460	TRACTOR 1150E	4	5,000	20,000
B2482	FLU 419	1	5,000	5,000
B2561	EBFL	6	5,000	30,000
B2566	TRK FL 4000IBS	15	4,000	60,000
B2567	TRACTOR RT ART	7	5,000	35,000
D0209	MK48 POWER UNIT	32	2,000	64,000
D0235	Semi-Trlr low bed m870	4	3,000	12,000
D0876	Container Hlr MK14	25	2,500	62,000
D0877	Trl/Wrk MK 15	2	4,000	8,000
D0878	TRL 5th Wheel MK16	4	1,500	3,000
D0879	TRL 20-TON	2	4,000	8,000
D0880	TRL Tank Water	24	750	18,000
D1001	TRV AMB	4	2,000	8,000
D1002	TRK AMB M1035	9	2,000	18,000
D1059	5-TON TRK	148	3,500	518,000
D1072	M817 (Dump)	4	3,500	14,000
D1125	TOW Carr	40	2,000	80,000
D1158	TRK Cargo M998	228	2,000	456,000
D1159	TRK ARMT EM1043	35	2,000	70,000
D1212	Wrecker M813/M936	5	4,000	20,000
E0796	AAVC 7A1	1	10,000	10,000
E0846	AAVR 7A1	14	10,000	100,000
E0856	AAVR 7A1	1	10,000	10,000
E0950	LAV Recovery	1	10,000	10,000
		715		1,765,000

Inadequate corrosion control at the first and second echelons is increasing repair costs after the equipment corrodes to the point where the Intermediate Maintenance Activity (IMA) corrosion facility must repair the equipment. IMA repairs are more costly as parts and subassemblies frequently must be replaced. In addition, the number of man-hours used by the IMA corrosion control facility for Marines to remove corroded parts, sand blast them, and then apply corrective coating to the equipment is much greater. [Ref. 15]

The above environmental and OSHA regulations are strictly enforced on base. The medical evaluation process, sizing and procuring masks, and training on the corrosion control process can take from seven to twelve weeks. Marines are "fully" productive for approximately three months of the 16 weeks that they are assigned to the facility. By comparison, the personnel that work at civilian sites normally perform this work as their primary job for much longer periods of time. This reduces the percentage of lost front-end time to prepare personnel to work on the equipment. This efficiency can be captured in the price to perform corrosion control.

C. BUDGETARY CONSTRAINTS

The 3rd Marine Regiment allocates funds to individual units to perform first and second echelon corrosion control on approximately 1200 pieces of equipment. The value of this equipment is approximately $48,000,000.

1. Combat Service Support Group-3

Once the equipment requires intermediate maintenance, it is turned over to CSSG-3. Funding for repairs at the IMA comes from the CSSG-3's budget. Their

$300,000 overall budget of includes only $80,000 for IMA corrosion control. The IMA corrosion control facility has to perform corrosion control that would normally be done at the DMA. The available funding is not adequate to do work that would normally be done at the DMA. In 1996, CSSG-3 received $250,000 from III MEF to cover additional costs attributed to corrosion control. This increased funding was still inadequate to cover all the respective costs. As a result, equipment has not received repairs when initially needed, or it has not been maintained at all. As of yet, this has not "deadlined" vehicles, but it has compromised equipment readiness and personnel safety. [Ref. 1]

Facing a similar problem, the Army has contracted with a government activity, located at Schofield Barracks, to perform intermediate corrosion protection/maintenance on 3000 vehicles. The Army has been very satisfied with the contractor's level and quality of service and their reasonable price. Upon contacting this contractor to inquire about servicing Marine vehicles, the vendor initiated the proposal process.

The Schofield Barracks activity proposed a price of approximately $2,500 per 5-ton truck. The price would vary depending upon the required work and would be tracked by vehicle serial number.

During this same period the CSSG-3 maintenance company commander contacted PHNS to see if they could perform the required corrosion control work. PHNS has had a significant decrease in their United States Navy workload as the number of ships and hence ship maintenance has decreased. PHNS stated that the local Marine Corps requirements were well within their production capacity. Also, they responded enthusiastically to the prospect of a contract with the United States Marine Corps.

As PHNS had been contacted prior to Schofield, an initial trial period contract was signed with PHNS. To date, $250,000 has been spent at PHNS and an additional $210,000 was requested from III MEF for FY97. This money was to fund repair of the most severely corroded equipment. [Ref. 4]

Table 3-2 shows that it would require $1,765,000 to have the most seriously corroded 715 pieces of equipment processed through the PHNS facility.

2. Transportation Costs

Vehicles requiring depot level maintenance are typically transported to MCLB, Barstow CA. Roundtrip shipping costs are $6,600.00 per 5-ton vehicle. Alternatively, the cost to drive the vehicles and equipment to PHNS or Schofield Barracks is very small.

The transportation costs to the DMA at Barstow CA for corrosion protection make it a poor option. Obviously a solution must be found that can be effective in Hawaii.

D. COST EFFECTS OF CORROSION

Corrosion greatly reduces the vehicles' service life expectancy. This, in turn, costs the military tens of thousands of dollars per truck. [Ref 31] In addition, the military is now held strictly accountable for ensuring that equipment and vehicles are maintained to their full service life expectancy. The constantly decreasing maintenance budgets do not accommodate corrosion control at the required level. There is no indication that budgets will increase in the next several years; in fact they will likely decrease.

With any vehicle, it is more cost effective to conduct regular preventative maintenance (PM) than to periodically send the vehicle to the DMA for major repairs. Unfortunately, the environment in Hawaii prohibits effective organizational preventative corrosion control, leaving major repair the only option.

E. CHANGE PROCESSES

The 5-ton vehicles in Hawaii now range in age from seven to ten years. As these vehicles enter the window in which assemblies and subassemblies are normally replaced, logistics planners need to consider how to accomplish this without major disruption to combat units.

1. Reengineering

Corrosion control coupled with the regular maintenance procedures is a short-term solution. The process only barely keeps pace with the problem, assuming that funding is even available. The process in Hawaii should be reengineered to get ahead of this problem.

The current supply procedures and fifth echelon maintenance regulations require replacing assemblies and subassemblies at the DMA. Because funding in insufficient to send all vehicles to the DMA, vehicles are not getting the needed parts. The facilities in Hawaii have tried to adapt to the situation and do whatever it takes to keep the vehicles and equipment operational. These ad hoc procedures need to be reevaluated and revised to reflect the current real world situation facing that the Marine Corps faces at Kaneohe Bay.

2. Corrosion Coatings

Industry has developed several alternatives to the Marine Corps' current process of a phosphate pre-treatment, primer, and CARC topcoat. Testing has proven that the current CARC topcoat does not bond well to the primer. This bondability issue is a key problem for the Marine Corps. [Ref. 31]

There are alternative corrosion coatings that offer better overall corrosion protection with little or no increase in cost. The current phosphate pre-treatment is still considered to be the most practical base coat. This base coat can be covered with the most important layer, the primer. Zinc-rich primers are impermeable to moisture migration and offer protection against galvanic corrosion. This primer can then be covered with a topcoat containing vapor corrosion inhibitors. This has proven to be long lasting and durable. The key point to remember in the corrosion coating process is that the combination of coatings must achieve good bonding between all the coating layers. To satisfy the current Marine Corps requirement of having protection against chemical agent, the CARC can be applied to the topcoat stated above. [Ref. 31]

The above mentioned combination of coatings is but one process that could improve the current corrosion control process. There are a great number of companies that offer anti-corrosion coatings-- from those mentioned above to arc metal spray guns. Each has advantages and disadvantages ranging from high cost to handling considerations. The alternative corrosion coatings will be discussed further in chapter IV.

IV. ANALYSIS OF ALTERNATIVES

This chapter details the alternative means by which the United States Marine Corps could address vehicle corrosion control maintenance. All of the alternatives considered are EPA compliant. All the alternatives' facility costs will be treated as sunk costs except for the new Intermediate Maintenance Activity (IMA) corrosion facility.

Each of the four alternatives is evaluated on the basis of corrosion repair cost per 5-ton truck, personnel needs, vehicle turnaround time, throughput capacity, the Marine Corps involvement and the primary military service focus of the facility. The results of the research are consolidated in table 4-1. No separate repair parts, to include repair of assemblies and subassemblies, are included in the corrosion repair process, except for the DMA cost per vehicle which is a complete rebuild cost.

A. BUILD CENTRALIZED IMA CORROSION FACILITY

The new state of the art facility was estimated to cost $2.7 million in 1987 with an estimated construction time of 15 months. This option has not been recently considered due to the large initial facility cost; therefore, a revised figure is not available. The cost of civilian labor at this facility is estimated to be approximately $3,500 per vehicle. As labor is roughly substitutable across government businesses, the same figure is used as that at Pearl Harbor Naval Shipyard.

Marines can be used in this facility, but that is not attractive to the Marine Corps in a time of manpower downsizing. Civilian labor is less expensive to train when a

TABLE 4-1

ANALYSIS OF ALTERNATIVE METHODS FOR CORROSION CONTROL

	Facility Cost	Cost per vehicle[1]	Personnel Needed	Vehicle Downtime	EPA Compliance	Throughput Capacity[4]	USMC Participation	Facility Focus
Central Corrosion Facility Kaneohe Bay	$2.7 million[2]	$3,500[3]	30 Civ/Marine	1-3 weeks	Yes	24 Month	High	Marine Corps
DMA Barstow, CA	N/A	$30,631[5]	N/A	8-12 weeks	Yes	24 Month	Medium	Marine Corps
Pearl Harbor Naval Shipyard	N/A	$3,500	N/A	1-2 weeks	Yes	24 Month	Low	Navy
Maintenance Division Schofield HA	N/A	$2,500[6]	N/A	1 week	Yes	24 Month	Low	Army
Commercial Source	N/A	$2,500[7]	N/A	Unknown	Yes	24 Month	Low	Marine Corps
Current IMA Facility Kaneohe Bay	N/A	$3,500	15 Marines.	<1 week[8]	No	36 Month	High	Marine Corps

1. Unit corrosion repair cost per 5-ton truck
2. Based on 1987 estimate
3. Conservative estimate based on PHNS cost
4. For all 1200 pieces of equipment
5. Complete rebuild price
6. Average price based on cost of labor at $35 per man-hour
7. Estimate based on cost at Schofield Barracks
8. Vehicles are brought into the facility when space is available

comparison is made with the cost of a Marine from time of entry at the recruiter's office to the point where he is qualified to work on vehicles. The performance of the civilians is equal to that of the trained Marines. This facility's requirements are designed to utilize six working stations with five personnel at each. The throughput of the centralized corrosion facility, manned at the above level, would easily meet the need of a 24 month rotation. This would further be facilitated by performing only corrosion related repairs and ensuring that other maintenance be performed via job order at the existing CSSG-3 maintenance facility.

The Marine Corps would retain oversight of this facility. This is indifferent as to who is performing corrosion work in the facility, whether it be Marines or civilians. The Marine Corps would program the workload and prioritize requirements in accordance with USMC requirements. Additionally, the facility would fall under normal Marine Corps policy for inspections, budgeting, logistics, hazardous material storage and disposal, and personal health concerns that need to be carefully administered.

As a final note for this alternative, an important consideration that needs to be addressed is the response to a contingency operation in the Pacific area of operations. This facility would have the ability to stand up full time and operate three shifts to ensure all vehicles are combat ready. This is an advantage compared to PHNS and Schofield Barracks, which will be discussed later, where the Marine Corps is not the primary focus. The Marine Corps enjoys a lower priority than the owning services at those other alternative facilities.

B. TRANSPORT THE TACTICAL WHEELED VEHICLES (TWV) TO DMA, BARSTOW CA

The procedures are currently in place to transport TWVs and equipment via cargo ship to southern California. Transportation from the point of entry is then conducted via flatbed truck or railcar to DMA, Barstow CA. Once the vehicle arrives at the DMA, it goes through the standard complete rebuild process.

The cost of the facility is a sunk cost and is not considered. All the relevant costs of running the facility are included in the rebuild price per piece of equipment. A program uniquely for corrosion control is no longer available at the DMA. The complete rebuild price for a 5-ton truck is about $30,000. Incorporated into this cost is $6,600 for roundtrip transportation. This high price associated with a complete rebuild makes this option price prohibitive. In FY97 only seven vehicles from Hawaii were sent to the DMA in Barstow, CA.

The throughput capacity at this facility is adequate to meet the needs of Marine Corps equipment in Hawaii. However, in the event of a contingency operation, there would, more than likely, not be enough time to have all the vehicles needing corrosion maintenance transported to the DMA and returned to Hawaii.

This facility is a great way to handle the rebuilding of vehicles within the United States, but the combination of cost, transportation time, and lack of a dedicated corrosion control program makes this option less than attractive for the Marine Corps equipment in Hawaii.

C. OUTSOURCE THE CORROSION CONTROL

There are two opportunities to outsource the corrosion control to other government activities in Hawaii. The two available government sources for this study are Pearl Harbor Naval Shipyard (PHNS) and the United States Army Schofield Barracks facility. The facilities and personnel are currently in place for both activities. These facilities have the ability to perform corrosion control processes that meet Marine Corps' standards. Most of the work in the corrosion control process is labor intensive. In order to achieve the greatest savings at each of these facilities, a steady flow of work is needed to stabilize labor costs. Besides outsourcing to government activities, contracting the corrosion work to the private sector must be considered.

1. Pearl Harbor Naval Shipyard

Pearl Harbor Naval Shipyard is operated by the United States Navy. The facility is located approximately 27 miles from the Kaneohe Bay base, the site of the Marine Corps' motorpools. This facility has available capacity to take on additional work. As a result of this, PHNS has offered to perform corrosion repairs that would meet Marine Corps standards, provided that Marine Corps transports the vehicles to their facility. A fixed price is charged for each vehicle without regard to the extent of corrosion. The corrosion repair price per 5-ton vehicle is $3,500. Because this facility is a government maintenance activity, if costs exceed the prices charged, then prices will be raised and vice versa.

The personnel required to run the corrosion control program are currently employed by PHNS. They are the same workforce that performs repairs on the U.S.

Navy ships. Extensive coordination and maintenance programming need to be accomplished to balance the workload at this facility. The accurate programming of vehicles into the facility will result in a turnaround time of one to two weeks. The throughput capacity meets the Marine Corps' needs for a 24-month rotation cycle.

The Marine Corps' involvement in this alternative is to deliver, inspect, and pick up the vehicles from the facility. This is considered to have a low impact on the Marine Corps.

As a final point to this option, the focus of this corrosion control facility is the U.S. Navy. The Navy's ship maintenance takes precedence over the needs of the Marine Corps. This focus on the Navy could result in delays, extending the vehicle turnaround time. If a contingency should arise, the Marine Corps might have to find an alternative means to perform corrosion maintenance.

2. Maintenance Division At Schofield Barracks Hawaii

The Maintenance Division operates a corrosion repair facility at Schofield Barracks. The facility is located approximately 25 miles from the Marine Corps' motorpools. This facility charges their corrosion repair prices on the basis of an individual piece of equipment. The amount of corrosion damage determines the price that is charged to the Marine Corps. The labor rate charged is a flat $35/hour plus the cost of materials. For the purpose of this analysis, the cost per 5-ton truck is expected to average about $2,500. However, this can vary greatly depending on the extent of the corrosion. The lower price associated with the corrosion maintenance at Schofield

Barracks is attributed to a more modern, "high tech" work area. This facility makes wide use of the latest tools and processes which result in fewer labor hours per 5-ton truck.

The facility is currently operating at a level that meets the Army's needs and has the capacity to hire additional personnel to service the Marine Corps' needs in Hawaii. Hiring of additional workers would be handled by the Schofield maintenance management personnel and would not affect costs to the Marine Corps. The Schofield facility has the ability to meet the Marine Corps' needs for a 24-month rotation cycle.

The proper programming of vehicles through the Schofield facility will result in a vehicle turnaround time of one week. This is the current turnaround time that the Army is now experiencing with similar vehicles.

If the Marine Corps should choose this alternative, their responsibility would be the same with PHNS, which is to deliver, inspect, and return the vehicles to Kaneohe Bay.

The primary focus of the Schofield corrosion facility is the United States Army. In peacetime operations this is not a concern as the facility has adequate throughput capacity to handle the needs of the Marine Corps. However, if a contingency operation should arise, the Army's needs would take precedence over those of the Marine Corps. In this case the Marine Corps would be required to find an alternative source for the corrosion repairs or handle the added workload at the IMA corrosion facility.

As a final point, the Schofield facility has outstanding relations with the operating units. It uses surveys to determine areas in which their operations can be improved. In

addition, they maintain close contacts with commercial companies engaged in the business of corrosion control.

This option combines low cost corrosion repairs, adequate throughput capacity and quick turnaround of vehicles. In addition, the Marine Corps could expect the same quality service that the Army has been given.

3. Commercial Source

The above two alternative maintenance facilities are operated by the government. Commercial vendors may present opportunities for both competitive bidding and advanced anti-corrosion processes. A recent anti-corrosion research study has been done by Science Applications International Corporation (SAIC) focusing on the 5-ton truck. Corrosion data for this study was collected from Marine Corps studies, quality deficiency reports, personal interviews, and by visual inspections of vehicles. SAIC has determined that if an additional $1,900 were spent to add various coatings to specific parts during the corrosion maintenance rotation, the life of the 5-ton truck would be extended. [Ref. 31]

SAIC examined anti-corrosion methods, which would provide better corrosion protection for new vehicles, remanufactured vehicles, and vehicles scheduled for regular maintenance. This report focuses on anti-corrosion methods pertaining to remanufactured vehicles but the processes also apply to vehicles that are scheduled for regular maintenance, such as those in service in Hawaii.

Approaches for maximizing corrosion protection at the most affordable cost were based on tradeoffs. Expensive corrosion resistant materials were weighed against coating the base metal structure with a corrosion resistant coating. The considerable expense of

the corrosion resistant base material did not justify the added life of the material. The report findings applicable to repair of fielded equipment involved the use of corrosion resistant coatings. Alternative protective coatings have been developed by several companies, including Corrosion Technologies, Cortec Corporation, Teknichem Corporation, TAFA Incorporated.

Each of the processes incorporated the following steps. The first step in the corrosion process is to sufficiently strip down the truck to access the corroded areas or components in order to properly clean and apply anti-corrosion coatings. The parts or subassemblies must be evaluated for soundness and repairability. The repairable parts are then gritblasted or immersed in a caustic solution to properly prepare them for follow-on coatings. The primer, topcoat, and sealer must be applied before the base metal becomes contaminated by such things as human body oils and machine oils to effect the maximum resistance to corrosion. The recommended corrosion prevention approaches, along with the costs of application are shown in Appendix C.

a. Primer

Primers have two functions-- 1) provide corrosion protection and 2) provide improved bondability to the base metal. The primers are typically applied by use of an immersion bath system but can be applied by a spray system. Three primers were considered in the SAIC report.

The first is the iron phosphate primer. This primer can applied using the immersion bath system or sprayed over the bare metal material with the overspray being recaptured. The phosphate primer has been applied to vehicles and equipment for many

years. This primer provides adequate corrosion protection, good bondability characteristics, and no major hazardous material handling concerns beyond VOCs--all at an affordable cost.

Second is the manganese primer. This primer requires the use of an immersion bath system. The temperature of the manganese must reach 200° F to bond to the bare metal. This pretreatment has the best anti-corrosion characteristics and excellent bondability. However, the cost and difficulty of application remove this pretreatment from consideration.

Finally, zinc phosphate primer can be applied by immersion bath for a thicker coating or by a spray system with the overspray being recaptured. This system provides excellent corrosion protection, good bondability, and costs only slightly more than the iron phosphate pretreatment. A major concern is that zinc requires special handling due to its effects on the human body.

Cortec Corporation has developed new primers and topcoats that bond to and form an ionic layer on the pretreatment. Cortec VCI-365, VCI-389, and VCI-375 coatings contain vapor corrosion inhibitors (VCIs) that are long lasting and migratory. These coatings vary in composition from a two-part epoxy system, water-based topcoat, and water-based primer, respectively. Each exhibits excellent protection in salt fog, as well as satisfactory adhesion strength and anti-abrasion characteristics.

Pure metal, metal alloys, and ceramic coatings provide maximum

protection for metallic base materials when used as a primer. These coating are generally not used because of high cost and their difficulty of application. They require very high temperature (greater then 800° F for zinc) immersion bath systems.

Another expensive coating deposits pure metal material by use of an arc spray gun. The arc spray gun allows the operator to deposit the plasma or flame to achieve the desired density and bond strength. Although the corrosion resistance is excellent, the application equipment is expensive and the process requires very clean surfaces. Therefore, this methodology is not suitable for Marine Corps vehicles in Hawaii.

b. Topcoat

The purpose of the topcoat is to give the desired color characteristics to the metal. The composition of the topcoat usually does not provide an impermeable moisture barrier nor anti-abrasion characteristics. It is important that the topcoat adhere to the primer coat and provide good bondability with the sealant coat.

c. Sealers

Sealers are applied to the topcoat to prevent intrusion of moisture as well as provide a damage prevention layer for the "paint system." The sealant coating is a thick thixotropic material and will be effective for a long period of time, given that it is not subjected to extreme abrasion or extreme heat. It is critical that the sealer bond well to the topcoat to avoid breakdown in the paint system.

The possibility exists for the Marine Corps to do a modest test program

using the various anti-corrosion coatings described above on small quantities of 5-ton trucks in operational units in Hawaii. The SAIC study provides good anti-corrosion candidate coatings that should be tried out. Test results could be run through a cost-benefit analysis and might lead to a more efficient anti-corrosion program than the Marine Corps presently uses. This might result in lower cost and greater corrosion protection. In addition, the equipment's rotation and lifecycle might be extended.

D. PARTIAL OUTSOURCE AND MAINTAIN CURRENT OPERATIONS

The current IMA corrosion facility is capable of continuing to run corrosion control operations on a small scale even though it cannot meet the 24 month throughput requirement. Large body panels, rolling stock larger than 5-ton trucks, and heavy engineering equipment could be outsourced. These large items should be outsourced because they require large amounts of workspace and a tremendous amount of labor. Fully exercising this option, the Marine Corps would improve its readiness condition. The USMC would continue to maintain the capability to perform corrosion control on equipment and vehicles while avoiding maintenance costs by using Marine labor for a large portion of the corrosion repairs.

Presently it appears that PHNS and Schofield Barracks offer the best opportunities to have the corrosion control maintenance performed.

In the event of a contingency operation when the Marine vehicles and equipment would become second priority to the Army, the CSSG-3 corrosion facility would be able to make up the added work by adding additional Marines.

The Marine Corps needs to test the various commercial alternatives on a sample lot of operational vehicles to determine the added benefits of alternative coatings. After 24 months of operational use, an analysis should be done to determine if any of the alternative coatings should be pursued.

Several alternatives have been presented that could benefit the Marine Corps. These alternatives provide possibilities for better use of resources. However, the bottom line is this: the current funding level is inadequate to correct the corrosion maintenance problem. A corrosion control budget of $1.5 million (rough order of magnitude) is essential to combat the corrosion problem.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Scarce resources have caused the Marine Corps to make major cutbacks in sustainment of programs. This reduction of resources has resulted in the underfunding of corrosion maintenance to an extent that reduces readiness of Marine Corps units in Hawaii.

The focus of this thesis has been finding the most immediate and cost effective way to address vehicle corrosion in Hawaii. The continuous underfunding of the corrosion program coupled with the lack of attention to this area is creating a huge problem for the Marines who operate and maintain these vehicles and equipment. This thesis has shown that there is a need for significant changes in budgetary and corrosion control policy. The lifecycle costs outstrip budgeted funds now needed to ensure these vehicles and equipment are kept combat ready.

Although the alternatives presented would make great progress in the fight against corrosion, fiscal constraints are realistic and cannot be ignored. The Marine Corps must first acknowledge the seriousness of the problem and then commit the necessary resources to correct the problem. The current CSSG-3 corrosion control budget barely scratches the surface of the problem. Without a commitment to resolving the anti-corrosion funding problem, it is only a matter of time before vehicles and equipment are deadlined. The current policy of sending 5-ton trucks to Barstow CA for complete rebuild does not answer the Marine Corps need to perform anti-corrosion maintenance on a 24 months cycle.

B. RECOMMENDATIONS

Marine Corps funding is expected to decrease further in the foreseeable future. In order for the Marine Corps to maintain its capabilities in Hawaii, they need to enhance their corrosion control program. As a result of this research the researcher has three recommendations.

First, fully fund the anti-corrosion maintenance effort in Hawaii. Given the seriousness of the corrosion problem, it is estimated that $1.5 million (rough order of magnitude) is needed annually to effectively combat the corrosion problem. Therefore, the corrosion budget of $340,000 needs to be increased (plus-up) of $1.2 million (rough order of magnitude).

Second, send the anti-corrosion maintenance work to PHNS or Schofield Barracks. The two government facilities in Hawaii could provide an immediate response to the Marine Corps' corrosion problem. Either facility has the throughput capacity to handle the needs of the Marine Corps. PHNS would, no doubt welcome the work as they need the USMC corrosion maintenance work in order to help maintain their workforce.

Finally, test and analyze the commercially available anti-corrosion approaches on vehicles operating in Hawaii. Modest testing of commercially available alternative corrosion coatings needs to be done on a small sample of operational vehicles. This then needs to be followed-up by a cost benefit analysis. The results of the analysis may provide a lower cost alternative that, once implemented, will reduce the expenditure of operation and maintenance funds for anti-corrosion maintenance.

C. TOPICS FOR FURTHER RESEARCH

The researcher suggests three additional topics for further research. These questions were encountered during the process of researching this thesis.

First, it is extremely important that the effects of corrosion be taken into consideration in the design phase of the MTVR. An investigation needs to be conducted to ensure that the current problems that the Marine Corps is now experiencing are not repeated with the MVTR. It has been proven elsewhere that good corrosion protection can substantially reduce corrosion effects.

Second, in the early 1990's, after the 3rd Marine Expeditionary Brigade was eliminated, resources were cut back dramatically. A thorough analysis needs to be conducted to refine the estimate of funding needed to repair the vehicles seriously damaged by corrosion and to conduct a long-term corrosion prevention/repair program for Marine Forces in Hawaii.

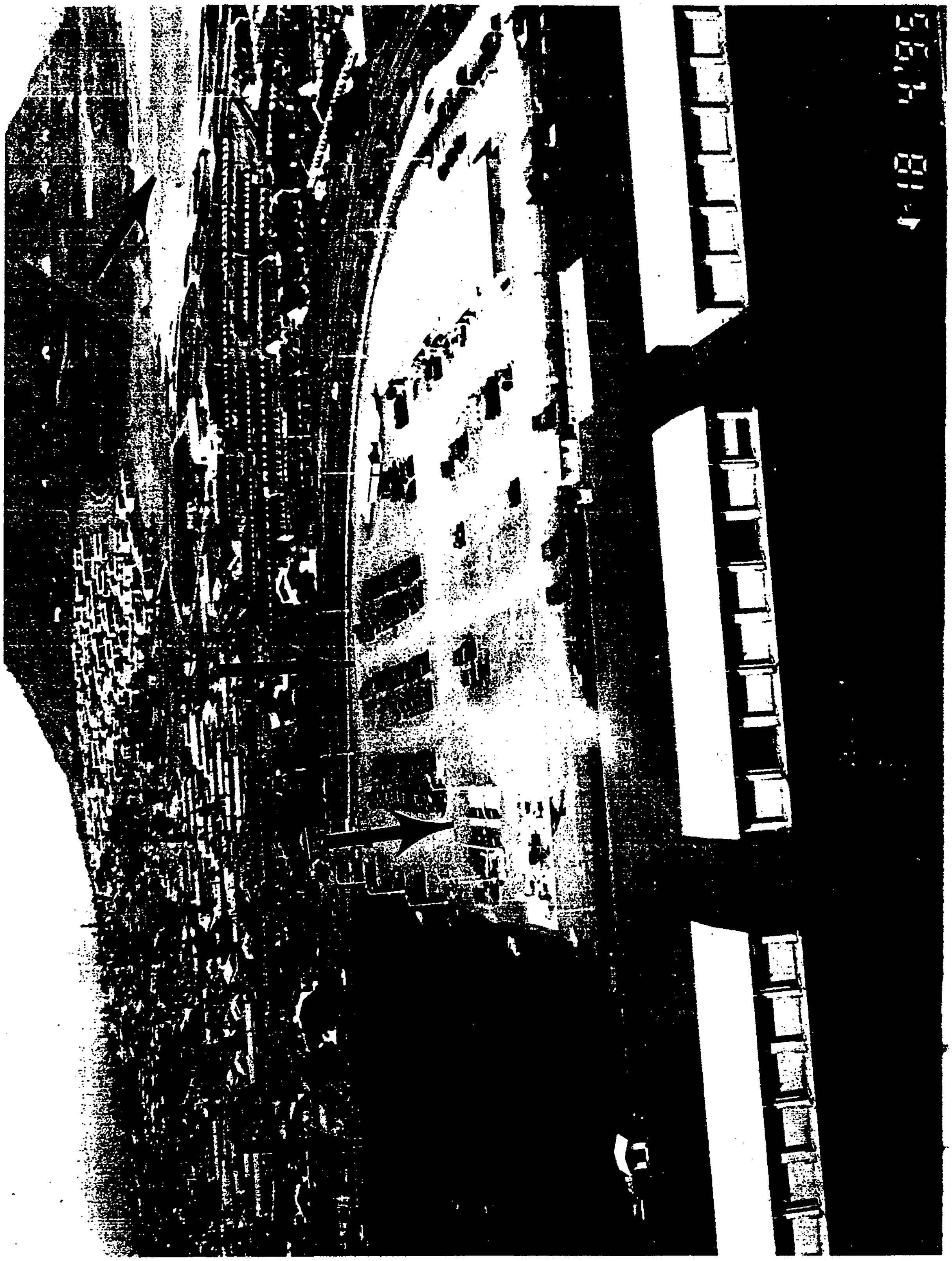
Finally, the cost benefit analysis needs to be pursued on an oil/water separator at the Pohakulua Training area, together with the cost of trucking adequate amounts of water to the area. Serious consideration should be given to this facility upgrade, as the initial costs may be pay off in long-term cost avoidance of corrosion repairs.

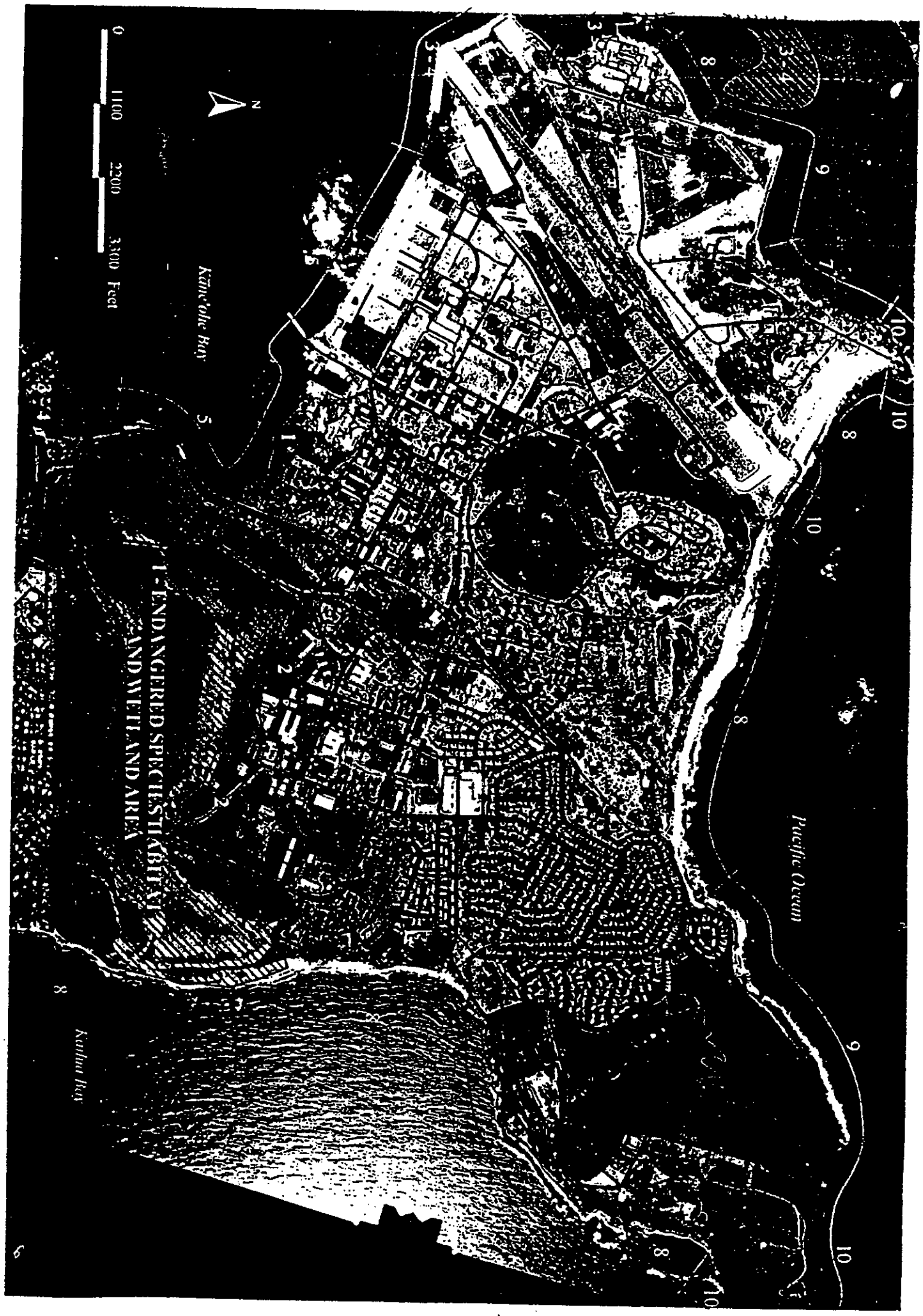
APPENDIX A. ACRONYMS

AAPPSO	Army Acquisition Pollution Prevention Office
ASTM	American Society for Testing and Materials
CAA	Clean Air Act
CARC	Chemical Agent Resistant Coating
CM	Corrective Maintenance
CMR	Consolidated Memorandum Report
CPAC	Corrosion Prevention and Control
CPC	Corrosion Preventive Compound
CRS	Cold Rolled Steel
CSSG	Combat Service Support Group
DMA	Depot Maintenance Facility
E-Coating	Electro-deposition Coating
EAC	Environmentally Assisted Cracking
EPA	Environmental Protection Agency
FAP	Fleet Assistance Program
FSSG	Force Service Support Group
HAZMAT	Hazardous Materials
HMMWV	High Mobility, Multi Wheeled Vehicle
IMA	Intermediate Maintenance Activity
IROAN	Inspect, repair only as necessary
LVS	Logistics Vehicle System

MAG	Marine Aircraft Group
MCLB	Marine Corps Logistics Base
MCO	Marine Corps Order
MEB	Marine Expeditionary Brigade
MT	Motor Transport
NACE	National Association of Corrosion Engineers
NEPA	National Environmental Policy Act
PHNS	Pearl Harbor Naval Shipyard
PM	Preventive Maintenance
PTA	Pohakuloa Training Area
RCRA	Resource Conservation Recovery Act
RIP	Repairable Issue Point
SCC	Stress-Corrosion Cracking (problem with stainless Steels)
TARDEC	Tank-Automotive Research Development, and Engineering Center
T/O	Table of Organization
TWV	Tactical Wheeled Vehicle
USA	United States Army
VOC	Volatile Organic Compounds
VCI	Vapor Corrosion Inhibitor

APPENDIX B. PHOTOGRAPHS OF KANEOHE BAY MOTORPOOL AREA

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Pacific Ocean
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T-ENDANGERED SPECIES HABITAT
AND WETLAND AREA

APPENDIX C. RECOMMENDED CORROSION PREVENTION APPROACHES FOR REMANUFACTURED 5-TONS

RECOMMENDED CORROSION PREVENTION APPROACHES
FOR REMANUFACTURED 5-TON TRUCKS

COMPONENT	RECOMMENDED PROTECTION METHOD	ESTIMATED COST
Frame assembly components	Clean-gritblast	2 1/10 hrs = $115.5
	Coat-arc spray-aluminum 0.003 min.	1 hr = $55.00*
	Prime-polyurethane spray	1/3 hr = $18.30
	Topcoat-carc spray	1/3 hr = $18.30
Frame bolts	Use manganese phosphate coated bolts with PTFE topcoat	$170.00*
Cab	Repair as necessary	
	Add Drain holes	1/4 hr = $13.75*
	Clean-gritblast	2 hrs = $110.00
	Coat-arc spray aluminum	4/5 hrs = $44.00*
	Prime-polyurethane spray	1/4 hr = $13.75
	Topcoat-Carc spray	1/4 hr = $13.75
Doors (2)	Repair as necessary	
	Add Drain holes	1/6 hr = $9.16*
	Clean-gritblast	3/4 hr = $41.25
	Coat-arc spray aluminum, all sides	1/2 hr = $27.50*
	Prime-polyurethane spray	1/6 hr = $9.16
	Topcoat-Carc spray	1/6 hr = $9.16
Hood	Repair as necessary	
	Add drain holes	1/6 hr = $9.16*
	Clean-gritblast	1/2 hr = $27.50
	Coat-arc spray aluminum	1/5 hr = $11.00*
	Prime-polyurethane spray	1/8 hr = $7.50
	Topcoat-Carc spray	1/8 hr = $7.50
Cargo body (Bed)	Repair as necessary	
	Provide drain holes as needed in stake pockets	1/4 hr = $13.75*
	Clean-gritblast	2 1/2 hrs = $137.50
	Coat-arc spray aluminum	1 1/2 hrs = $82.50*
	Prime	1/2 hr = $27.50
	Topcoat	1/2 hr = $27.50
Windshield frame	Repair as necessary	
	Add drain holes	1/5 hr = $11.00*
	Clean-gritblast	1/4 hr = $13.75
	Coat-arc spray aluminum	1/5 hr = $11.00*
	Prime	1/8 hr = $7.50
	Topcoat	1/8 hr = $7.50

COMPONENT	RECOMMENDED PROTECTION METHOD	ESTIMATED COST
Fuel tank	Replace with aluminum tank 55 gal. Replace with aluminum or composite straps	$300.00 ea. $15.00 ea. side
Metallic tubing and fittings 1/4", 3/8", and 1/2" OD	Replace all tubing with 316 series seamless stainless steel tubing and fittings	1/4" OD 50' @ $2.10/ft=$105* 3/8" OD 10' @ $2.50/ft=$25* 1/2" OD 5' @ $2.80/ft= $14* 40 fittings avg $2.50 ea.=$100*
Rubber hose with metallic fittings such as power take-off lines	Replace with hoses with 316 stainless steel fittings	To be supplied by Aeroquip Corp.
Front fenders	Repair as necessary Clean-gritblast Coat with arc spray aluminum Prime Topcoat	 1/3 hr = $18.30 1/6 hr = $9.20* 1/6 hr = $9.20 1/6 hr = $9.20
Air tanks	Clean-gritblast Coat with arc spray aluminum Prime Topcoat	1/6 hr = $9.20 1/10 hr = $5.50* 1/10 hr = $9.20 1/10 hr = $9.20
Miscellaneous Bolts, Screws, and Fasteners	Use manganese phosphate coated bolts with PTFE topcoat	$500.00*
Overlappng joints and crevices	Apply silicone rubber to overlapping surfaces prior to assembly. Apply bead of silicon rubber to seal crevices.	$40.00*
Electrical Connections	Treat all electrical connections with Corrosion X Marine on periodic basis determined by routine maintenance schedule	$15.00 per treatment*
Headlight Assembly	Replace all ferrous components with aluminum or molded composite	No cost impact

COMPONENT	RECOMMENDED PROTECTION METHOD	ESTIMATED COST
Muffler/Exhaust system, excluding exhaust manifold	Replace with aluminized 409 stainless steel or 316 stainless steel components	$300.00*
Engine and Exhaust manifold exterior surfaces	Gritblast Arc spray with aluminum Prime Paint	1/2 hr = $27.50*
Drivelines, U-joints	Clean-gritblast Coat with arc spray aluminum Prime Topcoat	1/5 hr = $12.00 1/6 hr = $9.20* 1/10 hr = $5.50 1/10 hr = $5.50
Battery and other storage boxes	Add drain holes Gritblast Coat with arc spray aluminum Prime Topcoat	1/6 hr = $9.20* 1/3 hr = $18.30 1/5 hr = $11.00* 1/6 hr = $9.20 1/6 hr = $9.20
Brake cables, heater cables	Spray with Corrosion X-Marine Repeat at normal maintenance	1/10 hr = $5.50*
Electrical connectors	Spray with Corrosion X-Marine Repeat at normal maintenance	1/10 hr = $5.50*
Aluminum wire for all items above		64 lbs @ $2.50 = $160.00*

* Delta cost increase for corrosion protection

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